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Bussell

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[54] **ALTERNATE ROOT TURBINE BLADING**

[75] Inventor: **Kenneth J. Bussell,** San Jose, Calif.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[52] **U.S. Cl.** **416/212,** 416/193, 416/220
[51] **Int. Cl.** **F01d 5/30**
[58] **Field of Search** 416/212, 220, 193

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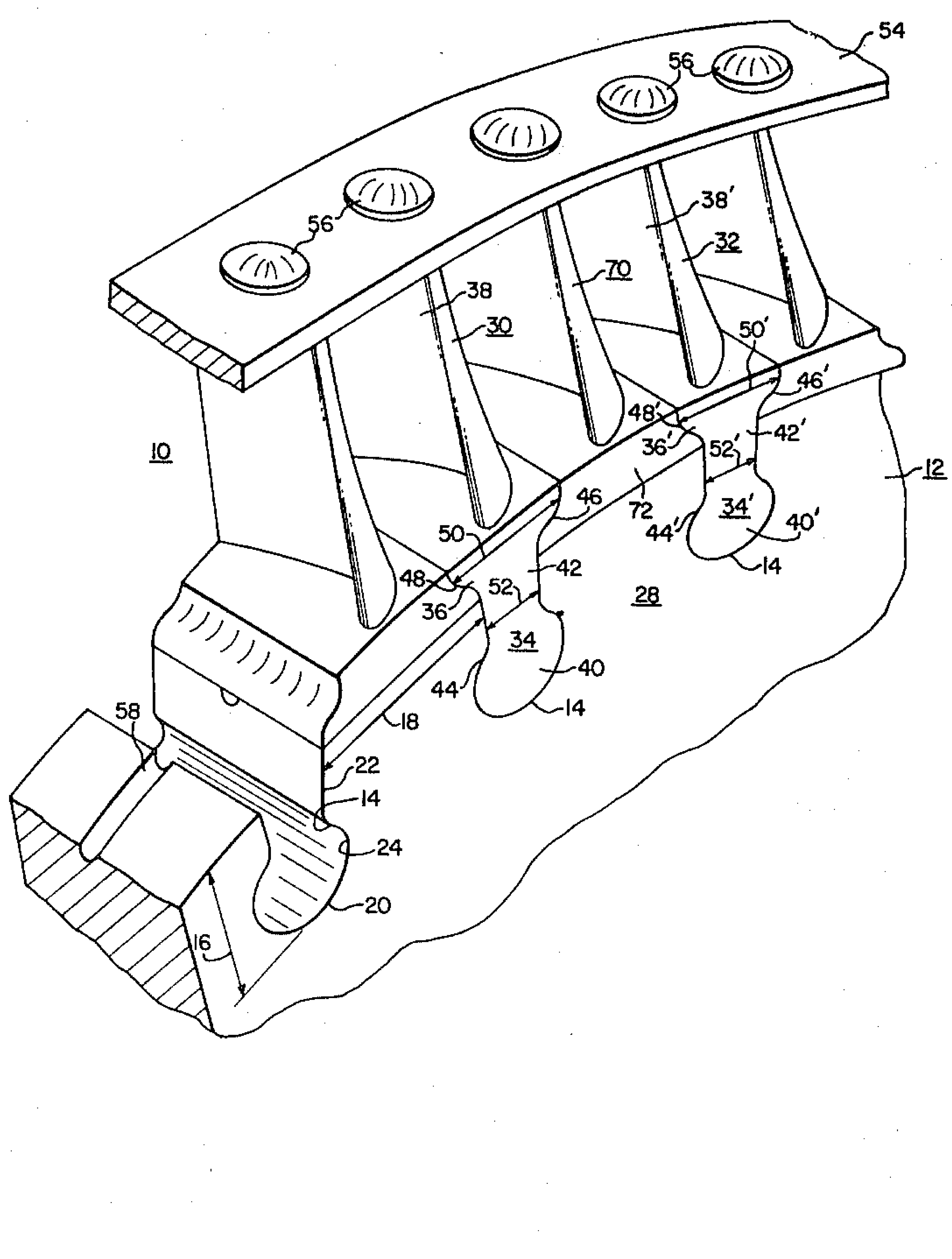
Primary Examiner—Everette A. Powell, Jr.
Attorney, Agent, or Firm—C. H. Telfer

[57] **ABSTRACT**

A rotor for an axial flow elastic fluid turbine apparatus. The rotor has a rotating shaft member having at least a first and a second rooted blade secured to the shaft. Each rooted blade has a platform portion thereon. A rootless blade, having a platform portion thereon, is disposed intermediate between each pair of first and the second rooted blades. The underside surface of each of the platforms on the rootless blades directly abuts the shaft member, with the platforms of the rooted blades contacting the platform of the rootless blades to radially secure the rootless blades in position. In addition, a protruding pin member diposed on the underside surfaces of each of the rootless blades engages a circumferential slot in the shaft member to axially secure the rootless blades.

8 Claims, 2 Drawing Figures



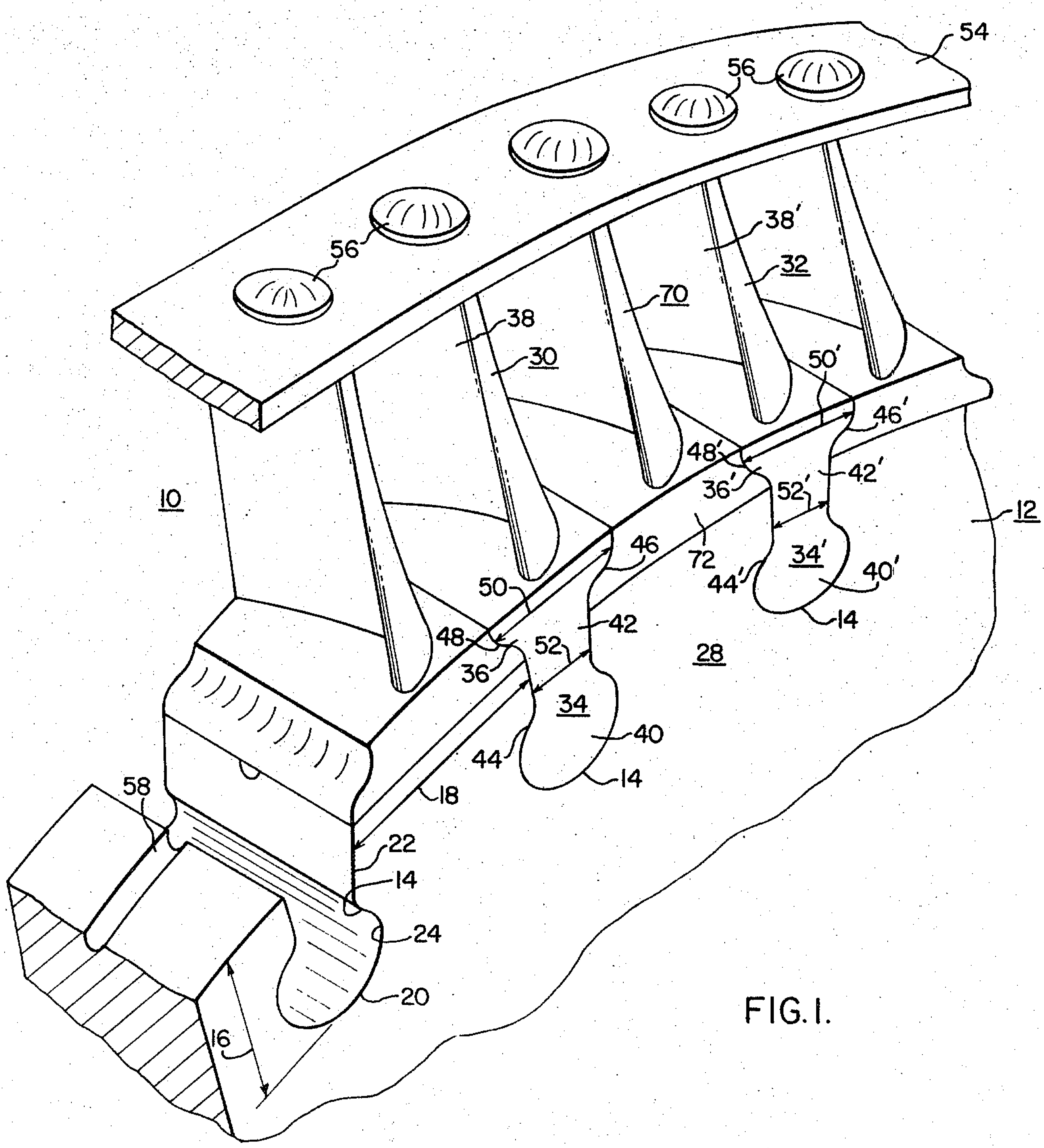

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FIG. I.

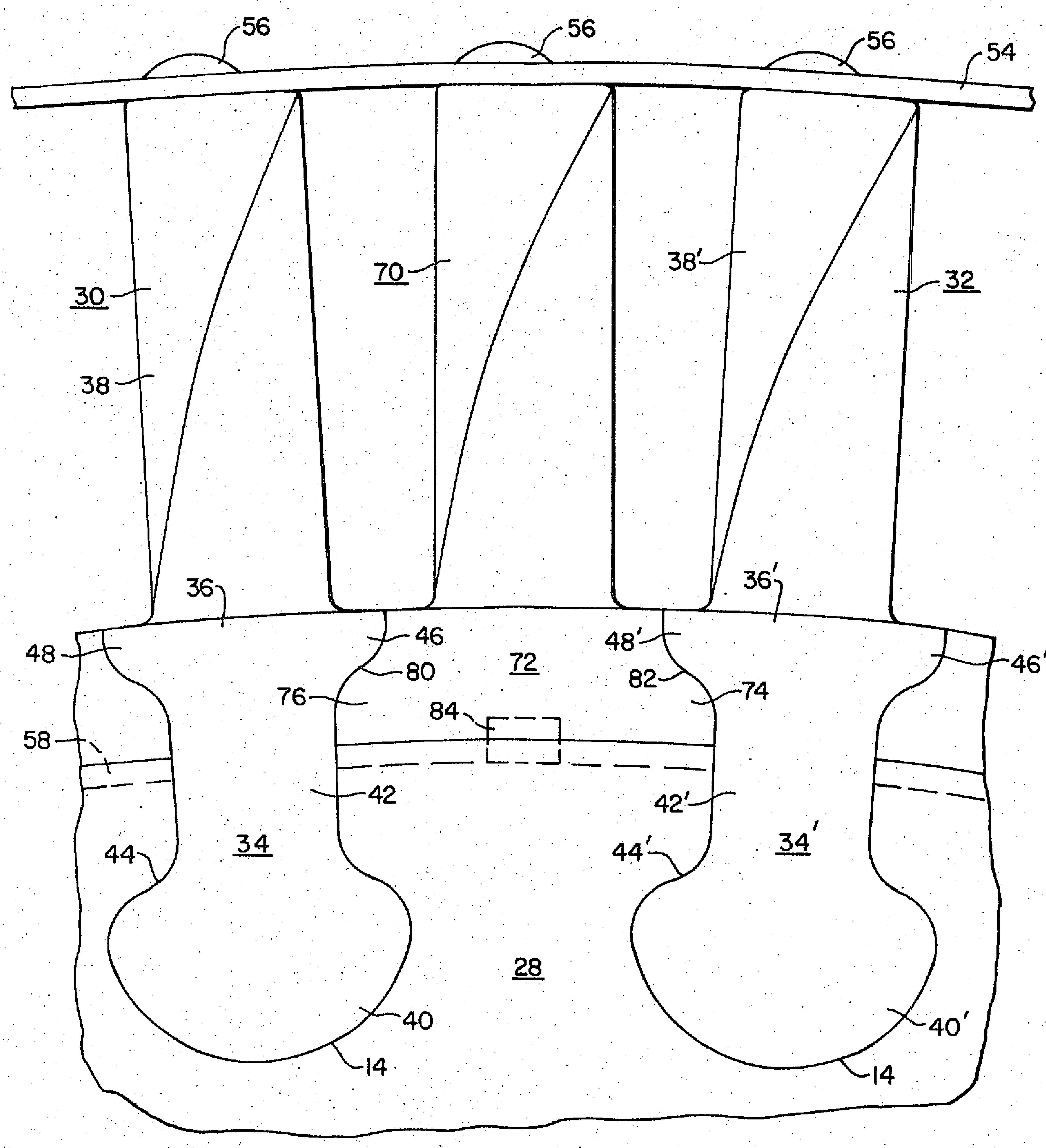
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FIG. 2.

ALTERNATE ROOT TURBINE BLADING

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The invention relates to axial flow elastic fluid turbine apparatus, and in particular, to a bladed rotor structure utilized in the turbine apparatus.

2. Description of the Prior Art:

In an axial flow elastic fluid turbine apparatus, a plurality of blade members are secured to a rotating shaft member by engaging a root portion of each blade with a substantially axial groove disposed in the rotor shaft. A common blade root configuration is the fir tree type, side entry blade root. The fir tree style root is a generally triangular shaped root, having a plurality of protrusions producing a serrated edge that extends from the base of the root toward the tip thereof. The root is usually curved and is received by the correspondingly curved groove disposed in the shaft member in such a way that the tip of the substantially triangular root is the radially innermost portion of the turbine blade.

Due to the complexity of the root shape, and the number of roots generally required around a given shaft circumference, geometry dictates that the fir tree root utilize an extremely small fillet portion between the root body and each serration, or tang, which extends from the root body. However, stress concentrations tend to form around these fillets which impose a high stress load on the blade root.

In addition to formation of high stress concentrations, it has been shown that the usual fir tree root configuration does not provide universal contact between all surfaces of the tangs and the rotor body. Thus, even under intermediate centrifugal force loading, universal contact between all surfaces of the tangs and the rotor body does not occur.

It is obvious, therefore, that high stress concentrations and the almost total reliance for radial restraint of the blades on the outer surfaces of the tangs leads to excessive stress and premature failure of the fir tree type root. Also, machining of the plurality of grooves that accommodate the fir tree roots is a time-consuming and expensive process.

In the prior art, attempts have been made to eliminate half the number of grooves required by disposing a plurality of rooted blades and inserting therebetween an intermediate "rootless" blade having a keyed portion thereon. The keyed portion of the intermediate blade engages a corresponding keyed portion on the platform of the rooted blades while the base of the intermediate blade rests upon a lateral protrusion from the rooted blades. An example of the prior art utilizing this technique is disclosed in the U.S. Pat. No. 3,702,202, issued to Bernales, and assigned to the assignee of the present invention. However, the complex shape of the blade root was not changed, and the stress concentrations found when utilizing the fir tree type root still remain.

SUMMARY OF THE INVENTION

The invention discloses a rotor for an axial flow elastic fluid turbine apparatus having a generally cylindrical rotating shaft member having a plurality of generally axial grooves spaced a predetermined circumferential distance about the periphery of the shaft member. A first and second rooted blade are disposed in adjacent shaft grooves. The root portion of each blade is comprised of a generally cylindrical knob portion and a rectanguloid neck portion connected thereto. The cylindrical knob poriton is the radially innermost portion of the blade root and has a large fillet forming the transition between the substantially cylindrical knob and the rectanguloid neck portion.

Both the first and the second rooted blades have a platform portion thereon. Disposed intermediate the adjacent rooted blades is a rootless blade having a platform portion thereon. The rootless blade is disposed immediately adjacent to and directly abutting the rotor shaft. The rootless blade is radially secured in position by contact between the platforms on rooted blade and the platform of the rootless blade.

A pin extending from the underside surface of the rootless blade platform engages a circumferential slot disposed about the periphery of the rotor shaft member to axially secure the rootless blade in position.

An object of the invention is to provide a blading arrangement for an axial flow elastic fluid turbine apparatus wherein each blade has a stronger, more efficient root configuration.

In addition, it is advantageous, and therefore a further object of the invention, to provide a blading arrangement for an axial flow elastic fluid turbine apparatus that provides an improved blade damper thereby improving the efficiency of the apparatus. A still further object of the invention is to provide a blade root configuration requiring half the number of axial grooves than have been heretofore required, thereby making the tooling operation on the grooves simpler and less expensive.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description of an illustrative embodiment taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of a portion of a bladed rotor structure embodying the teachings of the present invention; and

FIG. 2 is a side elevational view of a portion of the bladed rotor structure shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Throughout the following description, similar reference characters refer to similar elements of the drawings.

Referring to the drawings in FIG. 1, there is shown a perspective view of a fragment of a rotor structure **10** that is part of an axial flow elastic fluid turbine apparatus (not shown) while FIG. 2 illustrates an elevational view of the rotor **10.** The blade structure described by the teachings of this invention can be utilized on any blade array for an axial flow elastic fluid turbine apparatus.

The rotor structure **10** includes a portion of the rotor shaft **12.** As shown in FIGS. **1** and **2,** the rotor shaft **12** has a row of grooves **14** which extend axially about the periphery of the rotor shaft **12** and which extend radially inward a predetermined distance **16** from the surface of the rotor shaft **12.** The grooves **12** are spaced a predetermined circumferential distance **18** from each other and are similar to each other in shape and size. The grooves have a generally cylindrical knob slot **20** and a generally rectanguloid slot **22**, with a large fillet transition slot **24** between the cylindrical knob slot and the rectanguloid slot **22**.

The portion of the shaft member between adjacent grooves **12** is known to those skilled in the prior art as the "steeple," hereinafter referred to by reference numeral **28**.

A first rooted blade **30** and a second rooted blade **32** are attached to the rotor shaft **12**. The first rooted blade **30** has a root portion **34**, a platform portion **36** and an airfoil portion **38** extending radially outward from the platform portion **36**. The second rooted blade has a root portion **34'**, a platform portion **36'** and an airfoil portion **38'** extending radially outward from the platform portion **36'**.

The root portions **34** and **34'** of the first rooted blade and the second rooted blade, respectively, each have a cylindrical knob portion **40** and **40'** connected to a rectanguloid portion **42** and **42'**. A generous fillet portion **44** and **44'** is disposed between the knob portions **40** and **40'** and the rectanguloid neck portions **42** and **42'**.

The root portions **34** and **34'** of the first rooted blade **30** and the second rooted blade **32**, respectively, are axially inserted into adjacent axial grooves **14** as illustrated in the drawing.

The platform portions **36** and **36'** of the ifrst rooted blade **30** and the second rooted blade **32**, respectively, have a first lateral protrusion **46** and **46'** and a second lateral protrusion **48** and **48'**. The lateral protrusions provide the platform portions **36** and **36'** with a circumferential dimension **50** and **50'** that is greater than the circumferential dimension **52** and **52'** of the rectanguloid neck portions **42** and **42'** on the first rooted blade **30** and the second rooted blade **32** respectively.

The airfoil portions **38** and **38'** are connected to a circumferential shroud **54** by suitable means illustrated in FIG. **1** as a rivet **56**. A slot **58** extends circumferentially about the shaft **12**.

A rootless blade **70**, having a platform portion **72** thereon, is disposed intermediate between the first rooted blade **30** and the second rooted blade **32**. The underside of the platform portion **72** of the rootless blade **70** abuts directly against the steeple portion **28** of the rotor shaft **12**.

The platform portion **72** of the rootless blade **70** has a first lateral protrusion **74** and a second lateral protrusion **76** thereon.

The exterior surface of the lateral protrusion **74** of the rootless blade **70** is contacted by the underside surface of the lateral protrusion **48'** of the second rooted blade **32**. The exterior surface of the lateral protrusion **76** of the rootless blade **70** is contacted by the underside surface of the lateral protrusion **46** of the first rooted blade **30**.

The contact interface between the rootless blade **70** and the rooted blades **30** and **32** is illustrated by reference numbers **80** and **82** respectively. The platform portions **36** and **36'** of the rooted blades **30** and **32** respectively contact the platform portion **72** of the rootless blade **70** to radially secure the rootless blade **70** directly against the rotor shaft **12**.

The arrangement disposing the rootless blade **70** intermediate between the first rooted blade **30** and the second rooted blade **32** is repeated until alternate rooted and rootless blades are disposed about the entire circumference of the rotor shaft **12**.

The rotor embodied by the teachings of this invention differs from the prior art, and especially the aforementioned Bernales patent, in that the rootless blade **70** in this invention directly abuts against the steeple portion **28** of the rotor shaft **12**, while in the aforementioned Bernales patent, the base of the rootless blades abut a lateral extension of the rooted blades. These lateral extensions from the rooted blades in turn abut the steeple of the rotor shaft.

A pin **84** is disposed on the underside surface of the rootless blade and engages the slot **58** extending circumferentially about the periphery of the rotor shaft **12**. The engagement of the pin **84** in the slot **58** in the rotor shaft **12** axially secures the rootless blade **70** in position.

It is apparent that the root configuration **34** and **34'** utilized by the rooted blades **30** and **32** in this invention is a simple and easy to fabricate configuration, which will be less expensive to manufacture than are the fir tree roots utilized in the prior art.

In addition, the large fillets **44** and **44'** eliminates stress concentrations which were observed with the fir tree type root, thus preventing premature failure of the blade root caused by excessive stresses on the root. Also, since there are one half the number of rooted blades than were required in the prior art, fabrication of the rotor and the broaching time required to fabricate the axial grooves **14** is significantly reduced, thus reducing manufacturing expense.

By utilization of the alternate root blading embodied by the teachings of this invention, it is possible to provide an effective blade damper for the blades, thus improving the efficiency of the turbine apparatus.

As is well known to those skilled in the art, the rooted blades **30** and **32** and the rootless blade **70**, each have a different point of fixity, that is, a different point of attachment to the shaft **12**. The differing points of fixity between the rooted blades **30** and **32** and the rootless blade **70** insures that a different natural frequency of vibration will exist in the rooted blades **30** and **32** than in the rootless blade **70**.

Since this is so, whe vibrations are engendered within the rooted blades **30** and **32** and the rootless blade **70**, such vibrations emanating, for example, from the impingement of elastic fluid on the blades at the nozzles of the turbine apparatus, relative motion between the rooted and the rootless blades will occur. If all of the blades on a turbine had the same point of fixity, it is evident that no relative motion will be observed between the blades, since all blades will have the same natural frequency of vibration. However, since the points of fixity of the rooted blades **30** and **32** and the rootless blade **70** differ, relative motion will exist between the rooted blades **30** and **32** and the rootless blade **70**.

When vibratory forces are imposed upon the rooted blades **30** and **32** and the rootless blade **70**, and the relative motion between the blades has been initiated, the interaction of the rootless blade **70** with the rooted blades **30** and **32**, as illustrated at interfaces **80** and **82**, will result in heat energy being developed by the abrasion of the rootless blade **70** against the rooted blades **30** and **32**. The heat energy generated by the abrasion between the rooted blades **30** and **32** and the rootless blade **70** will absorb the vibratory energy in the blades, thus providing an effective damper for the blades that was unavailable with the prior art blades.

It is thus seen, that an improved rotor structure, utilizing at least a first and a second rooted blade, with an intermediate rootless blade disposed therebetween, provides an effective blade damper and also provides for ease of fabrication of a rotor member. The rootless blade is secured radially by contact between the platform portion of the rooted blade with the platform portion of the rootless blade. The rootless blade is secured in the axial direction by a pin and slot arrangement.

I claim as my invention:

1. A rotor for axial flow elastic fluid turbine apparatus comprising:

a shaft member having a plurality of axial grooves disposed circumferentially about the periphery thereof and having a surface area thereon, said grooves being a predetermined circumferential distance from each other,

a first rooted blade disposed in one of said plurality of axial grooves, said first rooted blade having a platform portion thereon;

a second rooted blade disposed in an adjacent axial groove, said second rooted blade having a platform portion thereon,;

a rootless blade having a platform portion thereon, said platform portion having an underside surface thereon, said underside surface of said platform portion of said rootless blade directly abutting said surface area on said shaft member, said platform portion of said first rooted blade and said platform portion of said second rooted blade contacting said platform portion of said rootless blade to radially secure said rootless blade in position against said shaft member and,

means for damping relative motion between said rooted blades and said rootless blade, said means comprising said contacting platform portions adapted so that relative motion between said rooted blades and said rootless blade generates a friction force therebetween to dampen said relative motion.

2. The rotor of claim 1, further comprising means for axially securing said rootless blade to said shaft member, said axial securing means comprising

a slot disposed circumferentially about the periphery of said shaft, and,

a pin member extending radially form said underside surface of said rootless blade, said direct abutment between said underside surface of said platform portion of said rootless blade and said surface area on said shaft permitting said radially extending pin member to engage said circumferential slot to axially secure said rootless blade to said shaft.

3. The rotor of claim 1, wherein said first and said second rooted blade each has a root member comprising a radially innermost substantially cylindrical knob portion,

a substantially rectanguloid neck portion connected to said knob portion, and

a transition portion disposed radially between said knob portion and said neck portion, said transition portion being disposed so as to prevent stresses from concentrating adjacent roots as said roots radially secure said rooted blades to said shaft, said knob portion and said transition portion being completely disposed radially beneath the surface of said shaft, a predetermined portion of said neck

being disposed radially beneath said surface of said shaft.

4. The rotor of claim 1, wherein said platform poriton of said first rooted blade has a laterally extending protrusion thereon,

said platform portion of said second rooted blade has a laterally extending protrusion; and,

said platform portion of said rootless blade has a first lateral protrusion thereon and a second lateral protrusion thereon, the underside surface of said platform portion of said rootless blade and the underside portions of said lateral protrusions of said rootless blade directly abut said rotor shaft, said lateral protrusion of said first rooted blade contacting said first lateral protrusion of said rootless blade, said lateral protrusion of said second rooted blade contacting said second lateral protrusion of rootless blade, contact between said rootless blade and said first rooted blade and said second rooted blade radially secures said platform portion of said rootless blade in the abutting relationship with said rotor.

5. The rotor of claim 4, wherein

said lateral protrusions on said first and said second rooted blades each have a smooth surface on the underside thereof,

said lateral protrusions on said rootless blade each have a smooth surface on the radially outer side thereof,

said smooth underside surfaces of said lateral protrusions of said first and said second rooted blades overlapping and contacting against said smooth radially outer surfaces on said lateral protrusions of said rootless blade,

said relative motion between said rooted and rootless blades generating said friction force along said overlapped and contacted smooth surfaces on said platforms of said rooted blades and said rootless blade to dampen said relative motion therebetween.

6. A rotor for an axial flow, elastic fluid turbine apparatus comprising:

a shaft member having a plurality of axial grooves extending radially into said shaft and arranged circumferentially about the periphery thereof, said grooves defining a predetermined surface area of said shaft therebetween,

a first and a second blade having a root thereon, each root being disposed in adjacent axial grooves, each root having a predetermined circumferential dimension at the point on said root radially adjacent said surface of said shaft,

said first and said second rooted blades each having a platform portion thereon spaced radially outward from said roots, said platforms each having a first and a second lateral protrusion thereon, the circumferential dimension on each blade between edges of said lateral protrusions being greater than said predetermined circumferential dimension of said root, said protrusions being spaced radially away from said shaft surface, each protrusion having a smooth underside surface thereon,

said first protrusion on said first rooted blade and said second protrusion on said second rooted blade each circumferentially overlapping a portion of said surface area between said first and said second rooted blades, and,

a rootless blade disposed between said first and said second rooted blades, said rootless blade having a platform portion having a first and a second lateral protrusion thereon, the greatest circumferential dimension of said rootless blade being disposed across said lateral protrusions,

said platform portion of said rootless blade having a smooth underside surface thereon, said lateral protrusions of said rootless balde having smooth radially outer surfaces thereon, said underside surface of said rootless blade platform directly abutting against said surface of said shaft between first and said second rooted blades,

said smooth, radially outer surface of said first protrusion of said rootless blade being radially beneath and overlapped by said smooth underside surface of said first lateral protrusion on said first rooted blade, said smooth radially outer surface of said second protrusion on said rootless blade being radially beneath and overlapped by said smooth, underside surface of said second lateral protrusion on said second rooted blade,

the smooth underside surfaces of said lateral protrusions of said rooted blades overlapping, contacting and abrading against the radially outer surfaces of said lateral protrusions of said rootless blade to radially secure said rootless blade to said rotor,

said rooted blades and said rootless blade being adapted so that relative motion between said rootless and said rooted blades generates a friction force between said smooth overlapping, contacting and abrading surfaces to dampen said relative motion between said rooted blades and said rootless blade.

7. The rotor of claim **6**, wherein said root portion which radially secures said first and said second rooted blades to said shaft comprises

a substantaily cylindrical knob portion;

a substantially rectanguloid neck portion connected to said knob portion, and,

a transition portion disposed radially between said knob portion and said neck portion,

said knob portion being the radially innermost portion of said root when said root is disposed in one of said adjacent axial grooves,

said predetermined dimension of said root being taken at a point on said neck portion adjacent said surface of said shaft,

said transition portion between said knob and said neck being disposed so as to prevent stress concentration adjacent said root as said root radially secures said blade to said rotor.

8. The rotor of claim **7**, wherein

said rooted blades are attached to said shaft by said root portions thereof at a first point of fixity therebetween, and,

said rootless blade is attached to said shaft by said rooted blades at a second point of fixity,

said first point of fixity being radially inward on said shaft from said second point of fixity,

said difference in points of fixity for said rooted blades on said rootless blade permitting relative motion to occur between said rooted blades and said rootless blade,

said rotor further comprising means for axially securing said rootless blades to said shaft, said means comprising

a pin member radially extending form said underside surface of said rootless blade, and

a slot disposed circumferentially about said shaft surface,

said direct abutment of said underside surface of said platform of said rootless blade against said surface of said shaft permitting said pin member to be radially inserted and radially engage said slot to axially secure said rootless blade to said shaft.

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